REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 17. Period--July 1 to September 30, 1945

Compiled by R. T. Cotton, Entomologist
Cereal and Forage Insect Investigations
Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture
Manhattan, Kansas

The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

WHEAT STORAGE

Studies on the Fluctuations of Insect Populations in Wheat Stored under Different Systems of Management*

The study of the fluctuations in insect populations in wheat stored in Ever-normal granary-type bins was continued during the quarter. Five-probe samples were taken bi-weekly from the upper southwest quadrant of 40 bins in the Management Series; and the number of insects by species was determined from the examination of the samples. A summary of the data obtained during the current year is given in table 1. The lesser grain borer (Rhyzopertha dominica F.) and the rice weevil (Sitophilus oryza L.) are classed as "weevils" in the table and all other species are combined as "bran bugs". The rice weevil was rarely taken during the present season. The comparative abundance of the different species, by months, is given in the following tabulation:

Species	Per cent of total		
	July	Aug.	Sept.
Flat grain beetle (Laemophloeus minutus Oliv.)	45.1	53.0	39.4
Saw-toothed grain beetle (Oryzaephilus surinamensis L.)	47.7	25.6	26.6
Lesser grain borer (Rhyzopertha dominica F.)	2.1	11.5	19.7
Long-headed flour beetle (Latheticus oryzae Waterh.)	0.8	7.8	12.4
Red flour beetle (Tribolium castaneum Hbst.)	3.2	1.5	1.5
Hairy fungus beetle (Typhaea stercorea L.)	0.5	0.2	0.1
Cadelle (Tenebroides mauritanicus L.)	0.1	0.1	0.1
Indian meal moth (Plodia interpunctella Hbn.)	0	0.1	0.1
Rice weevil (Sitophilus oryza L.)	0	0.1	0.1
Dermestids	0.5	0.2	0.1
Total number of insects observed	778	5068	6385

The rapid increase in the abundance of lesser grain borer during August and September appears to be characteristic since it has occurred in each of the three years covered by this study.

It may be noted from table 1 that there was a rapid increase in insect population during August and September in all untreated bins, particularly of the lesser grain borer, which constituted the bulk of the "weevil" population. The following tabulation gives the comparative populations in the several groups of bins, arranged in ascending order of weevil population as of September 15, 1945:

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* Reported by H. H. Walkden, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, Soils, and Engineering.

Management Practice	Number of insects per 1000-gram sample	
	Weevils	Bran Bugs
1000-bushel steel bins		
1. Fumigation in August and October	0	0.7
2. White walls and roofs	1.0	5.8
3. No treatment, 9% moisture	3.4	0.4
4. Fumigation in August	4.5	0.7
5. Turn, clean, and fumigate in September*	13.6	0.8
6. No treatment, 11.5% moisture	20.8	65.9
7. Fumigation in September**	21.3	20.2
2740-bushel steel bins		
1. Fumigation in August and October	0	0
2. Fumigation in August	0.2	0.3
3. Painted white and grouped for shading	0.3	2.6
4. White walls and roofs	0.9	11.4
5. Fumigation in September**	5.2	6.4
6. Turn, clean, and fumigate in September**	5.5	3.8

* Sample taken after turning and cleaning but before fumigation.
** Sample taken before the September fumigation.

It may be noted from the above tabulation that the practice of fumigation in August and October prevents the establishment of insect populations. While some infestation occurs in the white painted bins, past experience has shown that this does not become serious before being checked by cold weather. It is of interest to note that rather high weevil population in the bins of 9 per cent moisture grain.

Table 1.--Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1945.

Grain storage practice	Average number of insects per 1000-grams								
	Feb. 9	Apr. 1	June 1	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15
1000-bushel steel bins									
No treatment:									
9.3% moisture	0[1]	0	0.2	0	0	0.6	1.2	1.6	3.4
	0.4[11]	0	1.0	0.2	1.0	3.0	2.6	3.4	0.4
11-11.5% moisture	2.4	0	0.2	0.2	1.2	4.0	18.6	13.6	20.8
	9.4	8.4	11.4	3.8	9.5	38.8	73.6	67.0	65.9
White walls and roof	0	0	0	0.2	0	0	0.6	0.8	1.0
	3.0	0.8	3.5	1.0	1.8	4.8	8.8	10.6	5.8
Fumigation in August	0.2	0	0.1	0	0.9	2.6	4.9[F]	1.3	4.5
	1.5	0.1	3.4	1.9	7.9	9.9	20.3[F]	2.0	0.7
Fumigation in September	0.2	0	0	0	0.2	1.4	3.8	8.8	21.3
	0.4	0.4	2.4	1.0	1.6	6.6	14.8	29.2	20.2
Fumigation in August and October	0	0	0	0.1	0	0.5	0.7[F]	0	0
	0.1	0.1	0.2	0.1	2.2	1.5	4.6[F]	0.2	0.7
Turn, clean, and fumigate in September	0	0	0.8	0	2.4	2.0	1.6	6.4[T]	13.6
	0	0.4	0	0	1.6	2.8	0.4	1.6[T]	0.8
2740-bushel steel bins									
No treatment:									
White walls and roof	0	0	0	0	0	0	0.1	0	0.9
	0.7	1.7	1.4	0.1	1.1	4.2	6.8	9.8	11.4
Painted white and grouped for shading	0	0	0	0	0	0	0	0.4	0.3
	1.2	1.2	0.5	0.6	0.5	1.6	2.1	2.1	2.6
Fumigation in August	0.05	0	0	0	0	0.5	0.8[F]	0.2	0.2
	2.3	1.5	1.1	0.7	1.0	1.9	2.8[F]	0.7	0.3
Fumigation in September	0	0	0	0	0	0.6	0.6	2.1	5.2
	0.4	1.3	1.2	0.5	0.2	2.8	3.3	7.1	6.4
Fumigation in August and October	0	0	0	0	0	0.5	1.7[F]	0	0
	0	0	0	0	0.06	0.9	2.4[F]	0.1	0

(continued)

Table 1, continued.

Grain storage practice	Average number of insects per 1000-grams: Feb. 9	Apr. 1	June 1	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15
2740-bushel steel bins (continued)									
Turn, clean, and fumigate in September	0	0	0	0	0	0.2	0.7	2.7$_{T}$	5.5
	1.1	0.5	1.5	4.9	6.7	8.2	13.4	14.8	3.8
1500-bushel wood bins									
White walls and roof	0	0	0	0	0	0	0	0.2	0
	23.6	2.4	5.2	2.0	2.0	14.8	30.2	27.2	39.4
White walls	0	0	0	0	0	0	0.8	1.6	1.8
	2.8	0.8	1.6	0.6	1.8	10.0	24.8	22.8	30.8
Red walls	0	0	0	0	0	0.2	1.4	4.4	10.0
	3.6	1.2	3.2	2.6	9.8	54.0	166.0	132.0	206.2

Legend: ' Weevils: includes lesser grain borer and rice weevil.
" Bran bugs: al species except the weevils.
F Grain fumigated.
T Grain turned and cleaned.

Control of Insects Infesting Grain Stored in Wooden Farm Granaries by Means of Interior Wall Treatments

As indicated in Report No. 16, the walls of a total of 67 wooden farm granaries have been treated with various materials, principally DDT. It was planned to sample these bins at monthly intervals after they had been filled with the 1945 crop. However, it was found impracticable to carry out such a schedule. The bins were sampled shortly after filling, and it is hoped that they can be sampled again during October in order to observe insect population increases.

The July sampling consisted of observations on temperature, moisture, and initial insect population. The insect populations were uniformly low in all of the bins immediately after they were filled with the 1945 crop. The moisture content ranged from about 11.5 to 15.5 per cent. The grain in most of the bins ranged from 12 to 13 per cent.

Samplings later in the season are expected to show any differences in insect populations due to the various wall treatments.

Experimental Fumigation of Wheat and Other Stored Grains

A total of 57 bins, totalling approximately 68,000 bushels of grain, have been fumigated experimentally during the present season. Several compounds which showed high toxicity in laboratory tests, were tested under field conditions. The results of the experimental fumigation work are given in table 2.

In caulked steel bins, carbon tetrachloride, at a dosage of 1 gallon per 1000 bushels, gave nearly as good results as the mixtures of this compound with other toxicants.

In the tests with nitriles, a mixture composed of 2-chloroacrylonitrile, 5 per cent and 2,2,3-trichlorobutyronitrile, 5 per cent in carbon tetrachloride gave better kills than the mixtures containing a single nitrile.

2-chloroacrylonitrile has a boiling point of 89° C. and 2,2,3-trichlorobutyronitrile, 165° C. In the tests with these compounds it appeared that the former was giving better kills on the surface, while the latter gave better kills in the lower portion of the grain. Using a mixture of each in carbon tetrachloride, it appears that improved kills were obtained as shown in table 2.

However, the lachrymatory quality of these nitriles are objectionable, and further, the writer found that when spilled on the hand they cause severe dermatitis. The gas billowing out of the bin as the fumigant was applied also caused dermatitis on parts of the body exposed to it, particularly in the abdominal region.

The three iodides tested in this series showed promise, but their high present cost precludes their use.

The tests with ethylidene chloride in sorghum were disappointing, but past experience has shown that greatly increased dosages are required for that grain.

In wooden bins, carbon tetrachloride failed to give as good results as the mixtures of it with acrylonitrile at the low dosages used in these tests.

In connection with the fumigation of farm granaries, two bins were fumigated by applying the fumigant in a 2-foot band around the outer edge of the bin, in order to compare this method with an application evenly over the entire surface of the grain. Since infestation by the cadelle occurs largely around the outer edges of the bin, this method of application was tried with the idea of improving the kill next to the bin walls. In the two tests listed at the end of table 2, good kills were obtained next to the walls, but insects survived in the upper center portion of the grain mass. This would indicate that a portion of the fumigant should be applied to the center surface. Further tests of this method of application are planned for farm bins.

Table 2.--Summary of results of experimental fumigation of grain stored in steel and wooden bins, Hutchinson, Kansas, June - September, 1945.

Note: All bins contained stored wheat except as indicated in the table.

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent mortality: Surface Capsules	Per cent mortality: Overall kill	Per cent mortality: Natural population
I - STEEL BINS							
Carbon tetrachloride							
3-8	1000	6/16	1	93	92	93	--
1-16	1000	8/28	1	99	97	98	61
5-3	2740	9/5	1	88	93	90	81
2-chloroacrylonitrile, 10%; Carbon tetrachloride, 90%							
8-12	1000	6/18	1	98	100	99	--
8-12	1000	8/28	1	100	100	100	91
7-11	2740	9/5	1	90	100	93	80
Monochloroacetonitrile, 10%; Carbon tetrachloride, 90%							
11-12	1000	6/18	1	95	100	97	--
11-12	1000	8/28	1	100	100	100	93
9-4	2740	9/5	1	96	100	97	62
2,2,3-Trichloropropionitrile, 10%; Carbon tetrachloride, 90%							
4-10	1000	6/18	1	84	99	89	--
4-10	1000	8/28	1	99	100	99	--
10-4	2740	9/5	1	90	100	93	100
2,2,3-Trichlorobutyronitrile, 10%; Carbon tetrachloride, 90%							
3-9	1000	6/18	1	82	93	87	--
3-9	1000	8/28	1	99	98	99	100
9-5	2740	9/5	1	86	99	90	50
2-Chloroacrylonitrile, 5%; 2,2,3-Trichlorobutyronitrile, 5%; Carbon tetrachloride, 90%							
2-16	1000	9/4	1	100	100	100	--
5-1	2000	9/4	1	100	100	100	94
12-7	2740	9/4	1	100	100	100	75

(continued)

Table 2, continued

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent Mortality Surface capsules	Overall kill	Natural population
Ethyl iodide, 2%; Carbon tetrachloride, 98%							
1-7	1000	6/16	1	95	86	92	--
1-1	1000	9/7	1	100	100	100	80
Methyl iodide, 2%; Carbon tetrachloride, 98%							
1-6	1000	6/16	1	100	95	98	--
1/2-12	1000	9/7	1	100	100	100	93
n-propyl iodide, 2%; Carbon tetrachloride, 98%							
1-2	1000	6/16	1	99	97	99	--
1/2-13	1000	9/7	1	100	100	100	100
n-propyl bromide, 5%; Carbon tetrachloride, 95%							
2-14	1000	6/18	1	95	77	89	--
2-14	1000	9/7	1	100	97	99	82
tert-butyl bromide, 2%; Carbon tetrachloride, 98%							
2-9	1000	6/18	1	80	87	83	--
tert-butyl bromide, 5%; Carbon tetrachloride, 95%							
2-9	1000	9/7	1	99	100	99	91
Ethylene dibromide, 5%; Carbon tetrachloride, 95%							
4-16	1000	6/19	1	91	85	89	--
Ethylene dibromide, 10%; Carbon tetrachloride, 90%							
4-13	1000	6/19	1	90	99	93	--
Allyl chloride, 5%; Carbon tetrachloride, 95%							
1-16	1000	6/19	1	84	82	83	--
tert-butyl chloride, 2%; Carbon tetrachloride, 98%							
2-8	1000	6/19	1	62	72	66	--

(continued)

Table 2, continued

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent Mortality Surface capsules	Overall kill	Natural population
	tert-butyl chloride, 5%; Carbon tetrachloride, 95%						
2-8	1000	9/7	1	97	100	98	68
	Ethylidene chloride (Chloroethane)						
1-1	1000	6/12	4	90	98	92	88
	Ethylidene chloride, 75%; Carbon tetrachloride, 25%						
Sorghum, perforated floor							
4-1	500	8/27	8	46	91	69	0
4-2	500	8/27	8	69	94	81	15
4-3	500	8/27	8	49	100	75	57
	sec-butyl chloroacetate, 5%; Carbon tetrachloride, 95%						
3-15	1000	6/19	1	83	80	82	--
	Isopropyl chloroacetate, 2%; Carbon tetrachloride, 98%						
4-9	1000	6/16	1	89	73	82	--
	2-chloroethyl acetate, 2%; Carbon tetrachloride, 98%						
4-8	1000	6/16	1	94	80	89	--
	Ethylene dibromide, 5%; carbon bisulfide, 10%; ethylene dichloride, 25%; carbon tetrachloride, 60%						
2-16	1000	6/19	1	58	78	65	--
II - WOODEN BINS							
	Ethylidene chloride						
Wind ventilated, ventilators closed during fumigation Sorghum							
14-1	750	7/28	6	52	87	62	66
14-2	750	7/28	6	59	98	67	40

(continued)

Table 2, continued.

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent mortality: Surface capsules	Per cent mortality: Overall kill	Per cent mortality: Natural population
Ethylidene chloride, 25%; Carbon tetrachloride, 75%							
Wind ventilated, ventilators closed during fumigation							
Sorghum							
14-1	750	8/27	8	73	95	80	78
14-2	750	8/27	8	90	100	94	71
Carbon tetrachloride							
W. Burling	700	8/21	2	59	54	58	--
R. Burling	1200	8/21	2	76	87	78	--
13-5	1500	8/22	2	52	92	72	--
Acrylonitrile, 14%; Carbon tetrachloride, 86%							
F. Dade	700	8/20	2	71	98	80	--
R. Burling	700	8/21	2	96	100	97	--(Oats)
F. Dade	800	8/20	2	81	95	85	--
R. Burling	1200	8/21	2	86	100	89	--
13-6	1500	8/22	2	89	100	89	--
W. Burling	1700	8/21	2	87	100	91	--
W. Burling	2800	8/21	2	97	100	98	--
Acrylonitrile, 14%; Carbon tetrachloride 86%							
Fumigant applied in a 2-foot band around edge of bin							
F. Dade	700	8/20	2	92	89	91	--
R. Burling	1200	8/21	2	89	86	89	--

Effect of Treating Seed Wheat with DDT for Protection against Stored Grain Insects*

In previous investigations it was found that when insect-infested seed wheat was treated with DDT an excellent kill of most species of stored grain insects was obtained, even at dosages as low as 0.005% by weight. To determine what effect DDT would have on the prevention of infestation over long periods of time, seed wheat was treated with various dosages of DDT. This wheat was then placed in cotton bags and left for one year in a location where it would be subject to attack by a variety of stored grain insects. After a period of one year had elapsed, this wheat was examined. The results of this examination are shown in table 3.

No live insects were found in any of the treated lots, and no injury to the wheat was observed.

These tests indicate that very good protection of wheat can be obtained over a long period of time by small dosages of DDT when applied directly to the grain.

Table 3.--Condition of DDT-treated wheat after exposure to insect infestation for 1 year.

Treatment	Insects found
0.05% DDT by weight	No live insects
	50 dead lesser grain borer adults
	1 dead flour beetle adult
	13 dead cadelle larvae
0.025% DDT by weight	No live insects
	72 dead lesser grain borer adults
	8 dead cadelle larvae
	2 dead Indian meal moth larvae
0.005% DDT by weight	No live insects
	75 dead lesser grain borer adults
	2 dead flour beetle adults
	5 dead cadelle larvae
Check - No treatment	1500 to 2000 live lesser grain borer
	12 live flour beetles
	3 live cadelle larvae
	1 live Indian meal moth larva
	33 live Indian meal moth pupae
	1 dead cadelle larva

* Contributed by R. T. Cotton and J. C. Frankenfeld, Bureau of Entomology and Plant Quarantine.

Field Tests of Dusts for Protecting Seed from Insect Attack

The success attained in laboratory tests with dusts for the protection of stored seed from insect attack made it desirable to extend our observations to field scale operations.

Seed was treated in 4 different types of establishments that store seed on a commercial scale.

Observations have now been completed in one of these establishments and are reported herewith:

Tests in Seed Warehouse of Experiment Station

In this warehouse valuable seed used in experimental plantings on the agronomy farm of the experiment station are stored from season to season. For the most part the seed is stored in one-bushel lots in cotton sacks. However, some sorghum seed is stored unthreshed. The sorghum heads being hung suspended from the ceiling. Infestation in the sorghum heads is particularly difficult to control and infestation from this source spreads to the bagged seed so that it is continuously exposed to the attack of insects.

Wheat, sorghum, barley, and oats were treated with various combinations of dusts by dumping the seed into a galvanized metal tub and mixing by means of a shovel. After treatment the seed was resacked and placed in storage on shelves. The seed was treated on December 12, 1944. In August of the following year the seed was carefully examined to determine the efficiency of the various treatments. The type of seed and the treatment given are listed in table 4.

Table 4.--Record of seed treatment, December 12, 1944. Seed in one-bushel cotton sacks.

Lot No.	Type of seed treated	Treatment	Dosage--Per cent by weight
1	Wheat	Magnesium oxide - DDT 3%	0.1
2	"	"	0.1
3	"	"	0.05
4	"	"	0.05
5	"	Micro-Mag. - DDT 3%	0.1
6	"	"	0.1
7	"	"	0.05
8	"	"	0.05
9	"	Pyrophyllite - DDT 3%	0.1
10	"	"	0.1
11	"	"	0.05
12	"	"	0.05
13	"	Magnesium oxide (Michigan Chem. Co.)	0.1
14	"	"	0.1
15	"	"	0.1
16	"	"	0.1
17	"	Check	
18	"	"	
19	"	"	
20	"	"	
21	Sorghum	Magnesium oxide - DDT 3%	0.1
22	"	"	0.1
23	"	"	0.1
24	"	"	0.1
25	"	"	0.05
26	"	"	0.05
27	"	"	0.05
28	"	"	0.05
29	"	Micro-Mag. - DDT 3%	0.1
30	"	"	0.1
31	"	"	0.05
32	"	"	0.05
33	"	Pyrophyllite - DDT 3%	0.1
34	"	"	0.1
35	"	"	0.05
36	"	"	0.05

(continued)

Table 4--continued

Lot No.	Type of seed treated	Treatment	Dosage--Per cent by weight
37	Sorghum	Magnesium oxide (Michigan Chem. Co.)	0.1
38	"	"	0.1
39	"	"	0.1
40	"	Check	
41	"	"	
42	Barley	Magnesium oxide (Michigan Chem. Co.)	0.1
43	"	"	0.1
44	"	"	0.1
45	"	"	0.1
46	"	"	0.1
47	"	"	0.1
48	"	"	0.1
49	"	"	0.1
50	"	"	0.1
51	"	"	0.1
52	Oats	"	0.1
53	"	"	0.1
54	"	"	0.1
55	Barley	Check	

All treated seed was in perfect condition when examined, regardless of the dust used or the rate of application. In some cases larvae and pupae of the Indian meal moth were found spun up on the outside of bags of treated seed. No insects were found on the inside of the bags.

The bags of untreated barley and sorghum seed contained larvae and adults of both the Indian meal moth and the Angoumois grain moth. Little infestation was found in the untreated wheat, although some webbing of the Indian meal moth was observed.

Observations on seed stored at the other establishments will be completed during the fall.

Effect of Temperature, Moisture, and Dockage upon the Survival and Reproduction of the Red Flour Beetle

Investigations of the effect of temperature, moisture, and dockage on the survival and reproduction of the red flour beetle were conducted at a constant temperature of 90° F. Table 5 gives the weekly percentage of survival in 9, 12, and 15% moisture wheats with varying amounts of dockage over a 10-week period. In general this series of tests substantiates the findings of previous tests, in that the percentage of survival increases as the moisture content and the percentage of dockage is increased. As was noted in previous tests, the percentage of survival is not affected by dockage if the percentage of moisture is 15%. In the 9 and 12% wheat, the percentage of survival increases with increased amounts of dockage up to 1%. Additional amounts of dockage have no apparent beneficial effect on the survival of this species. One percent of dockage being apparently sufficient to assure adequate food for the adults. Nine percent moisture wheat is too hard to provide favorable food for the adult beetles as shown by the decrease in the percentage of survival in the clean wheat. The addition of 0.5% dockage appears to provide sufficient food for a few weeks but this amount of dockage is insufficient to insure life for a very long time. In the lots containing amounts of dockage of 1% or above, there is no significant difference in the percentage of survival.

The apparent discrepancies in the 12% moisture series is not explainable.

In the 15% moisture wheat there is no difference in the percentage of survival in the different dockage variant lots, indicating that wheat with a moisture content of 15% is soft enough to permit ready feeding by the adult stage of this species.

From the standpoint of reproduction, however, the amount of dockage is very important. Table 6 shows the number of pupae recovered from the various moisture and dockage series at the end of 10 weeks. In the 9% series there is no consistent increase in reproduction due to increased amounts of dockage. This inconsistency at present unexplainable, is probably due to individual differences of females in their ability to adjust themselves to subnormal conditions. Irregularities in the 12% moisture series is due to high mortality of adults.

In the 15% moisture series there is a consistent and significant increase in reproduction as the amount of dockage is increased.

Table 5.--Percentage of survival of red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 90° F.

Moisture content of wheat and food media	Percentage of survival after 1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks	8 Weeks	9 Weeks	10 Weeks
9% Wheat										
Clean wheat	55	0								
Same + 0.5% dockage	100	100	100	100	100	90	15	10	10	10
Same + 1.0% dockage	95	90	90	90	90	80	70	70	70	60
Same + 2.0% dockage	100	100	95	95	95	95	90	90	85	80
Same + 4.0% dockage	85	85	85	80	80	75	70	65	65	65
Same + 8.0% dockage	95	95	90	90	90	90	90	90	80	75
12% Wheat										
Clean wheat	90	90	85	70	65	50	30	20	20	20
Same + 0.5% dockage	100	100	95	95	95	95	95	65	45	40
Same + 1.0% dockage	100	95	90	85	75	75	75	75	65	60
Same + 2.0% dockage	100	100	100	50	40	35	35	35	35	35
Same + 4.0% dockage	100	100	40	0						
Same + 8.0% dockage	100	90	35	5	5	5	5	5	5	5
15% Wheat										
Clean wheat	100	95	95	95	95	95	95	95	90	90
Same + 0.5% dockage	100	100	100	100	100	100	100	100	95	90
Same + 1.0% dockage	95	95	95	95	95	95	95	95	95	95
Same + 2.0% dockage	100	95	90	85	85	85	80	80	80	80
Same + 4.0% dockage	100	95	95	95	95	95	95	95	90	90
Same + 8.0% dockage	100	100	95	95	95	95	95	95	95	95

Table 6.--Number of pupae recovered in 9, 12, and 15% moisture wheat with varying amounts of dockage at 90° F. after 10 weeks.

Food media	Number pupae recovered in 9% wheat	12% wheat	15% wheat
Clean wheat	0	31	57
Same + 0.5% dockage	35	89	94
Same + 1.0% dockage	0	96	143
Same + 2.0% dockage	32	83	241
Same + 4.0% dockage	1	53	295
Same + 8.0% dockage	33	94	310

Effect of Temperature and the Moisture Content of Wheat upon the Survival and Reproduction of the Granary and Rice Weevil

Table 7 lists the biweekly survival of granary and rice weevil adults held at a constant temperature of 80° F. in 9, 10, 11% moisture wheat.

In 9% moisture wheat the mortality of both the granary and rice weevil was high after one week. At the end of five weeks all rice weevil had died and by the end of the ninth week all the granary weevil were dead. In 10% moisture wheat the percentage of survival was low for both species at the end of 3 weeks. Subsequent examinations showed a gradual reduction in survival until by the end of the 13th week all of the rice weevil were dead and all but 3 of the granary weevil adults had died. In 11% moisture wheat only a slight mortality occurred by the end of the 3rd week, but a very high mortality was observed at the end of five weeks. At the end of the 7th week practically all rice weevil had died. In the case of the granary weevil a gradual reduction in survival occurred, so that at the end of 13 weeks there was an average survival of only 12%.

Adult longevity in both species is greatly influenced by temperature in addition to grain moisture. Life is much shorter at high temperatures than it is at lower levels.

Total reproduction at the end of 13 weeks for the two species in 9, 10, and 11% moisture wheat is shown in table 8. With both the granary and rice weevil significant increases in reproduction occur as the moisture content of the wheat is increased. No reproduction of the rice weevil was observed in the 9% moisture wheat at this temperature.

Table 7.--Survival of granary and rice weevil adults in 9, 10, and 11% moisture wheat at 80° F.

Moisture content of wheat and insect used	Percentage of survival after						
	1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks
9% Wheat							
Granary weevil	56	26	8	1	0		
do	83	39	3	2	0		
Rice weevil	55	19	0				
do	37	11	0				
10% Wheat							
Granary weevil	93	56	19	12	9	1	0
do	81	55	18	11	10	7	3
Rice weevil	93	79	11	3	2	1	0
do	80	70	10	2	1	0	
11% Wheat							
Granary weevil	100	92	29	27	25	23	16
do	94	83	18	12	12	10	8
Rice weevil	95	84	1	1	0		
do	94	80	5	1	0		

Table 8.--Reproduction of granary and rice weevil in 9, 10, and 11% moisture wheat at 80° F. during a 13-week period.

Percent moisture wheat	Granary weevil			Rice weevil		
	I	II	Ave.	I	II	Ave.
9%	22	24	23	0	0	0
10%	422	445	433	326	107	217
11%	1510	739	1125	884	672	778